Computational design process modeling

Conference or Workshop Item

Proceedings of 25th International Council of the Aeronautical Sciences, 3-8 September, 2006, Hamburg, Germany. ISBN 0-9533991-7-6.
Refereed final draft of a published paper at ICAS 20006.

COMPUTATIONAL DESIGN PROCESS MODELING

Marin D. Guenov*, Libish*, Dunbing Tang*, Helen Lockett*
*School of Engineering, Aerospace Engineering Group, Cranfield University,
Bedfordshire, MK43 0AL, UK
Tel: 44-1234-754612, Fax: 44-1234-758203
Email: [M.D.Guenov, Libish.2003, D.Tang, H.Lockett]@cranfield.ac.uk

Keywords: *Incidence Matrix, Design Structure Matrix, Computational Plan, Conceptual Aircraft Design, Process Modeling*

Abstract

In the conceptual design phase, relatively simple equations and functions (or compiled code) are used to describe the aircraft and to perform trade-off studies. The latter require an optimal execution sequence in order to reduce computational cost and design time, respectively. The focus of this paper is the dynamic derivation of the optimal computational plan for each study so that the designer could focus on designing the aircraft rather than managing the process flow. Two methodologies, the Design Structure Matrix (DSM) and the Incidence Matrix are used for the computational process modeling. The incidence matrix describes the relationship between variables and equations/models. The DSM has been used to express the dependency relationships between the models and also, after manipulation, to produce the solution process. The designer specifies the independent (known) variables first. Then the variable flow is modeled using the Incidence Matrix Method (IMM). It determines how data flows through the models, and also identifies any strongly connected components (SCCs). The second step is to rearrange all equations/models hierarchically in order to reduce the feedback loops in each of the identified SCCs. This is achieved by the application of a genetic-based algorithm. Subsequently all SCCs and non-coupled models are assembled into a macro model which forms a global DSM. The global DSM is further rearranged to obtain an upper triangular matrix which defines the final model execution sequence. A simple aircraft sizing example is presented to illustrate the proposed method and algorithm. Advantages of the method include improved efficiency and the ability to deal with both algebraic and numerical models as well as with multiple outputs per model.

1. Introduction

The decisions taken during the conceptual design phase commit the majority of the aircraft lifecycle costs, but also offer the greatest opportunity for innovation. The latter depends to a great extent on the ability to explore a large number of novel configurations in a relatively short space of time. Improving the conceptual design process in this respect involves several issues. In the first place, it should allow the starting point of the design study to depart from an existing configuration, otherwise the final result may end up being very similar to the original. Such freedom is often limited in practice due to the fact that many assumptions related to traditional designs may have already been hardwired into the existing compiled codes. Secondly, a greater flexibility of the computational process is needed in terms of what is considered an input or an output variable. This should depend solely on the objectives of the study. Such flexibility requires a process which would combine bottom-up composition of possibly hundreds of equations and models or black boxes (compiled chunks of modular code). These represent parametric geometry and layout configuration, aerodynamic performance, propulsion, flight dynamics and so forth. Following this, the process needs to perform a top-down